ORIGINAL ARTICLE

The Ultrachopper tip: a wound temperature study

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ABSTRACT • RÉSUMÉ

Purpose: To determine the thermal characteristics of the Ultrachopper and its thermal properties in varied viscosurgical substances.
Design: Experimental study.
Participants: Not applicable.
Methods: The Ultrachopper (Alcon, Inc) tip with the Infiniti (Alcon, Inc) handpiece was attached to a thermistor and placed in a test chamber filled with either an ophthalmic viscosurgical device (OVD) or balanced salt solution (BSS). The thermistor allowed for continuous monitoring of temperature from baseline and the change that occurred over 60 seconds of continuous run time.
Results: Mean maximum temperature in each OVD exceeded 50°C over the first 25 seconds of continuous run time. The mean maximum temperature was statistically significantly higher with all OVDs ($p < 0.0001$) when compared with BSS. A small but statistically significant difference in mean maximum temperature was shown between Healon 5 (AMO, Inc) and Viscoat (Alcon, Inc) ($p < 0.05$). The linear increase in temperature was statistically significantly different with all OVDs compared with BSS ($p < 0.0001$).
Conclusions: The thermal properties of the Ultrachopper tip demonstrate a heat-generating capacity that achieves published thresholds for risk for wound burn.

Objet : Établir les caractéristiques thermiques de la tête Ultrachopper et de ses propriétés thermiques dans une variété de substances viscochirurgicales.
Nature : Étude expérimentale.
Méthodes : L'embout Ultrachopper (Alcon, Inc.) joint à la pièce à main Infiniti (Alcon, Inc.) était attachée à un thermistor et placée dans une chambre d'essai remplie soit de dispositifs viscochirurgicaux ophtalmiques (DVO) soit de solution salée équilibrée (SSÉ). Le thermistor a permis de surveiller constamment la température à partir de la base et l'évolution survenue en 60 secondes d'utilisation continuelle.
Résultats : La moyenne de température maximale de chaque DVO a dépassé 60 degrés Celcius dans les 25 premières secondes d'utilisation continue. La moyenne de température maximale était, de façon statistiquement notable, plus élevée que tous les DVO ($p < 0,0001$) comparativement à la solution salée équilibrée. Une petite, mais statistiquement significative, différence dans la moyenne de température maximale s'est manifestée entre Healon 5 (AMO, Inc.) et Viscoat (Alcon Inc.) ($p < 0,05$). La croissance linéaire de la température différait de façon statistiquement significative de toutes les DVO comparativement à la SSÉ ($p < 0,0001$).
Conclusions : Les propriétés thermiques de l'Ultrachopper démontre une puissance thermique qui atteint les seuils publiés du risque de brûlure de la plaie.

Cataract extraction using phacoemulsification is the most commonly performed surgical procedure in the United States, and complications from the frictional heat generated (wound burn or contracture) have been well documented.[1,2] Multiple wound-temperature studies have implicated various causes in the origin of a wound burn.[3–14] Advances in surgical equipment have recently been introduced to phacoemulsification surgery, and these have yet to be studied and quantified in terms of risk for wound burn.

The Ultrachopper (Alcon, Inc, Forth Worth, Texas, USA) is a recently developed modification of the standard phacoemulsification handpiece tip. The tip is flattened with a mild downward angulation and two small aspiration ports placed laterally. It is designed to assist in chopping the nucleus in routine cataract surgery and has been touted to be particularly helpful in very dense nuclear cataract cases. Our clinical experience would support this claim; however, to our knowledge, no peer-reviewed study has evaluated this technology to better understand its strengths and potential weaknesses in the setting of cataract surgery. Anecdotal reports of wound burn with the Ultrachopper have been discussed (personal communication, Alan Crandall, MD), and although presumed incidence is low, the potential is present. Our aim is to provide understanding of the Ultrachopper with regard to heat generation and wound burn potential.

Wound burn has been reported at temperatures as low as 44.2°C in porcine eyes.[3,4] Another study reports that wound burns have been seen in cadaver eyes at a temperature of 50°C or higher after only several seconds of phacoemulsification.[12] It has been demonstrated that different ophthalmic viscosurgical device (OVD) materials can propagate heat due to differences in their exothermic properties, thus increasing the risk for wound burn with more highly exothermic OVDs.[13]

The purpose of this study is to evaluate the heat-generating capacity of the Ultrachopper in different OVD

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materials under strict laboratory test conditions. In these experiments, the temperature measured in degrees Celsius (°C) will serve as a representation of generated heat.

Methods

An Ultrachopper tip on an Infiniti ultrasound handpiece (Alcon, Inc) was capped with a silicone sleeve test chamber filled with OVD material or balanced salt solution (BSS). The OVD materials that were individually tested include Discovisc (Alcon, Inc), Healon 5 (AMO, Inc, Abbott Park, Illinois, USA), and Viscoat (Alcon, Inc, Abbott Park, Illinois, USA). A thermistor wire probe was attached to the handpiece at a point that had been measured to match the area of the handpiece that approximates the point of wound contact. The thermistor wire probe (IT-24P; Physitemp Instruments) was connected to the BAT-10 multipurpose thermometer (Physitemp Instruments, Clifton, New Jersey, USA), which is accurate to ±0.1°C.

The handpiece was tuned and primed in the standard fashion as provided in the user manual (Alcon, Inc). The sleeve was filled with OVD or BSS, and the handpiece with the attached thermistor was inserted into the sleeve. A baseline temperature reading was obtained. The Infiniti (Alcon, Inc) was set to the following parameters for the surgical technique used with the Ultrachopper: 50% longitudinal power, 80% torsional power, aspiration rate of 20 mL/min, and vacuum of 80 mm Hg. The Infiniti (Alcon, Inc) machine settings were verified before initiating the experiment. Once verified, the pedal was engaged to full position 3 for 1 minute. Temperature readings were taken every 5 seconds from baseline to 1 minute. The sleeve and handpiece were observed under an operating microscope during each experiment. The handpiece and Ultrachopper tip were allowed to cool to baseline temperature, and the tip was rinsed with BSS and dried with a gauze sponge before proceeding with subsequent testing.

During testing, it was noted that aspiration of viscoelastic material occurred at approximately 25 seconds in each run with Viscoat. A single event of aspiration occurred with a Healon 5 run at 30 seconds. A single event of mechanical failure of the Ultrachopper occurred when the tip broke at its base in a Healon 5 run at 30 seconds. Because these events resulted in significant temperature changes after the event, it was determined that statistical analysis would be carried forward on the first 25 seconds of testing with each material. This time frame allowed a consistent comparison under similar conditions for each material.

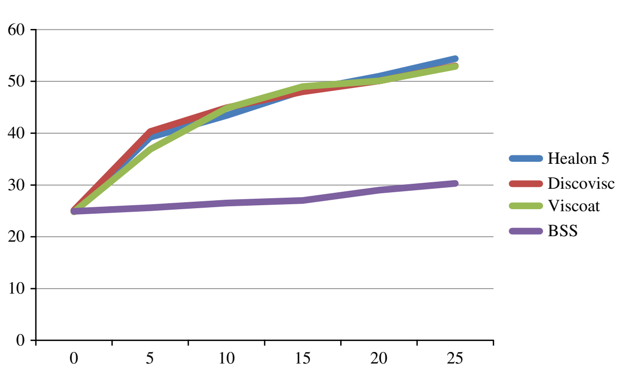

Fig. 1—Change in temperature (°C) over time (seconds).

Table 1—Mean maximum temperature

OVD	Mean (95% CI), °C
BSS	30.3 (29.1–31.6)
Discovisc	53.0 (51.8–54.2)
Healon 5	54.4 (53.2–55.6)
Viscoat	52.0 (50.8–53.2)

OVD, ophthalmic viscosurgical device; BSS, balanced salt solution; CI, confidence interval.

Results

All analyses are limited to the first 25 seconds of each run. An increase in temperature occurred at each time point with all substances throughout the first 25 seconds of time (see Fig. 1). The average of the maximum temperature over all time periods was calculated for each OVD (see Table 1). An analysis of variance was performed on the maximum temperatures to test the effect of OVD type on maximum temperature. BSS had a significantly lower mean maximum temperature than the other 3 OVD types ($p < 0.0001$). The Healon 5 maximum temperature, 54.4°C (95% CI 53.2–55.6), was significantly higher ($p = 0.0131$) than the Viscoat maximum temperature, 52.0°C (95% CI 50.8–53.2). There were no other statistically significant differences between tested OVDs.

A repeated-measures analysis of variance was performed to determine the effect of time on the temperature of the OVD. The linear term and quadratic term for interaction of time with each OVD type was statistically significantly different when compared with BSS ($p < 0.0001$ for both terms). There were no other pairwise differences.

Discussion

To our knowledge, this is the first peer-reviewed study of the Ultrachopper tip and is the first to review the heat-generating potential of the Ultrachopper. Because this device is often used in dense nuclear cataract cases, OVD testing included more commonly used cohesive or viscoadaptive agents that would be considered potentially useful in these cases.

As noted previously, wound burn has been observed in cadaveric studies at temperatures as low as 44.2°C.[3,4] The results of our study show that this temperature is reached within 10 to 15 seconds of continuous phacoemulsification energy in all OVD types tested with the Ultrachopper tip. The mean maximum temperature achieved in each OVD in the first 25 seconds of time also correlates with

reported wound burn risk in a human cadaveric study.[12] Some would argue that this amount of continuous phacoemulsification time is excessive relative to normal use; however, one unique feature of the Ultrachopper tip is the ability to run the tip effectively in both forward and reverse motion, allowing for the potential to run continuously for a longer period than is seen with a standard tip used in varied nuclear disassembly techniques.

Although direct comparison with other studies is limited because of different testing modalities, devices, and parameters, our mean maximum temperature is similar to other published studies. Olson et al.[7] recorded a maximum temperature of 57.5°C in the first 60 seconds of testing on the Legacy AdvanTec (Alcon, Inc) in a cadaver eye model. Soscia et al.[6] recorded maximum temperatures above 45°C within 29 seconds of continuous ultrasound using the Sovereign WhiteStar (AMO, Inc) system in a similar cadaver eye model. Han and Miller[11] measured temperatures above 50°C within 60 seconds using longitudinal phacoemulsification with the Infiniti (Alcon, Inc) phacoemulsification system in a BSS-filled silicone sleeve and varied suspended weights; however, in torsional only settings, they did not reach the 45°C threshold within the first 60 seconds of testing. Floyd et al.[13] recorded maximum temperatures of greater than 60°C in artificial chambers filled with varied OVDs in 20 to 60 seconds using the Legacy and Sovereign systems. Each of these studies carried out experiments that were designed to mimic tip occlusion by clamping flow. Although our study did not involve direct flow occlusion, the OVD materials we tested caused a similar functional scenario via occlusion of the small aspiration ports of the Ultrachopper because of the relatively low vacuum preset used with a peristaltic system. Despite the limitations of direct comparison with other studies, it is clear that the potential risk for wound burn is present with modern phacoemulsification technology and our study showed similar results using the Ultrachopper.

A statistically significant difference in the mean maximum temperature was found with all OVDs in comparison with BSS. When comparison of OVDs is entertained, the mean maximum temperature of Healon 5 was found to be statistically significantly higher than that of Discovisc and Viscoat. A previous study[13] showed a significant increase in temperature with varied OVD materials relative to BSS using the Legacy and Sovereign systems, with the largest temperature change seen with Healon 5 and Viscoat. This rapid acceleration in temperature rise is the reason a wound burn can occur precipitously with OVD once the process is initiated. Our results mirror most of these findings; however, we found that Healon 5 and Viscoat showed a difference in terms of maximum temperature and the rate of rise in temperature. The exact cause of this difference is unclear; however, it can be theorized that structural differences in the Ultrachopper and a standard phacoemulsification tip could result in differences in friction and heat generation that enhance minor variations in the exothermic properties of each OVD. Further study is needed to clarify this difference and its underlying cause.

The observed decline in temperature on aspiration of OVD material in this experiment teaches an important principle in avoiding wound burn with any phacoemulsification tip, including the Ultrachopper. Making an initial manoeuvre to aspirate OVD overlying the lens surface before initiating phacoemulsification can provide an area of BSS that will allow fluid flow and dissipation of heat energy in a more efficient and safe fashion. Any occlusion signal with the Ultrachopper should clue the surgeon to alter surgical technique and machine settings to minimize the risk for wound burn. In addition, it is important to ensure that correct handpiece position is maintained to allow proper dissipation of heat from the instrument.[6,14]

Limitations of our study include the in vitro nature of the testing apparatus, the limited number of study runs performed, and the limited number of OVD materials tested. Because of the limited number of testing runs performed, we did not vary the machine settings. Further study is warranted to improve our understanding of how variation in these areas relate to the risk for wound burn.

In conclusion, the heat generated with the Ultrachopper handpiece in OVD material reaches published thresholds for wound burn. There is a small but statistically significant difference in the peak temperature and rate of temperature increase in the different OVDs tested, and thus the OVD material may convey additional risk for wound burn. Attention to surgical technique can be used to mitigate this risk.

Disclosure: The authors have no proprietary or commercial interest in any materials discussed in this article.

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